IST-004527 ARTIST2
Network of Excellence
on Embedded Systems Design

Cluster Progress Report for Year 3

Cluster:
Adaptive Real Time

Cluster Leader:

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Policy Objective (abstract)

Adaptive real-time is a new discipline that developed to provide support to emerging applications (e.g., multimedia systems, robotics, telecommunications) characterized by reactive behaviors in highly dynamic environments. Achieving adaptivity in embedded real-time systems is a complex task that requires expertize from several disciplines, including operating systems, scheduling theory, network communication, control theory, quality of service management, and programming languages. To cover these issues, the ART cluster is currently organized into 5 activities:

1. JPIA Platforms: A common infrastructure for adaptive real-time systems
2. JPRA NoE: QoS Aware Components
3. JPRA Cluster: Flexible Resource Management for Consumer Electronics
4. JPRA Cluster: Real-Time Languages
5. JPRA Cluster: Dynamic and Pervasive Networking

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1. Overview

1.1 High-Level Objectives

The high level objective of the ART cluster is to build the fundamental bases of a new real-time software technology that can provide a more efficient and predictable support to the development of future embedded systems, characterized by high complexity and dynamic behavior. In particular, the new software technology should

- support scalability to facilitate the porting of control applications to different platforms;
- simplify the management of resources to control the growing complexity of embedded systems;
- increase programming flexibility, for specifying functional and performance requirements to simplify test and verification;
- increase system adaptivity to react to environmental changes, still providing a sufficient level of performance;
- be robust to tolerate transient and permanent overloads conditions due to wrong design assumptions or unpredictable changes.

Such features would have a concrete impact on European industry to reduce time to market, and improve software realiability and testabilty. To support industry in such a transition phase, new tools, algorithms and kernel mechanisms must be also provided. In this respect, the ART cluster is playing an active role, acting as a bridge between the academic and the industrial world, especially in the domain of consumer electronics, robotics, and telecommunications.

Such goals have been achieved by developing a research platform for real-time systems to share competencies, resources, and tools targeting at the development of control applications with performance and timing requirements. The use of a shared platform was essential for experimenting new real-time software technology, including novel scheduling algorithms, resource management techniques, energy-aware policies and overload handling approaches to increase robustness and predictability. Such a platform also facilitated the transfer of research results to industry, as allowed teaching practical knowledge of concepts and techniques. In addition, several solutions have been developed and tested in different partner sites, allowing the evaluation of the most appropriate approach for specific applications.

1.2 Industrial Sectors

The most important industrial fields that can benefit from adaptive real-time technology include Consumer Electronics, Industrial Automation, and Telecommunications.

Consumer Electronics (CE) products range from miniature cameras and MP3 players to advanced media servers and large displays. Utilizing available hardware and software resources in an optimal fashion is crucial both to save costs and to keep the competitive edge. Moreover, multimedia systems exhibit a highly dynamic behavior, since task execution times are often dependent on input data that are difficult to predict. As a consequence, these systems are prone to intermittent overload conditions that could degrade the performance in an unpredictable fashion. To address these problems, the ART cluster aims at integrating the most recent research results achieved in the real-time community to build flexible as well as predictable real-time systems that can react to load changes and perform QoS adaptation in a controlled fashion.

In the area of Industrial Automation there is a trend to search distributed solutions and to prepare hardware and software for connecting the general plant actuators, sensors and the controllers. Distributed solutions give a natural automation condition to common industrial needs as usually such plants are physically and topologically distributed. At the same time, there is an increase of demands for new options and improvements in the automation results, fetching more control of plant secondary data. This imposes a continuous increment in processing power and memory capacity that requires adaptivity at different levels of system operation. The contribution of the ART cluster in this domain is to investigate how to achieve predictability and adaptivity in distributed systems.

Embedded systems for telecommunications applications are mainly targeted to the interfaces between communication technologies and to coding/decoding operations. They may be considered real-time as they have timeliness requirements for some of the critical operations they must perform. The referred systems are microprocessor based platforms, often integrating a second processor (e.g., a DSP) devoted to specific functions, like MPEG coding. From the software point of view, a modern mobile phone typically consists of several million lines of code with use-cases involving large number of concurrent activities. A system supporting ``memory and temporal protection'' would allow safely mixing real-time and non real-time applications with the benefit of achieving a more scalable platform. The work on resource reservation carried out in the ART cluster is of crucial importance to manage the increased complexity of the applications in this domain.

1.3 Main Research Trends

Most of today's embedded systems are required to work in dynamic environments, where the characteristics of the computational load cannot always be predicted in advance. Still timely responses to events have to be provided within precise timing constrains in order to guarantee a desired level of performance. The combination of real-time features in dynamic environments, together with cost and resource constraints, creates new problems to be addressed in the design of such systems, at different architecture levels.

To cope with dynamic environments, a system must be adaptive; that is, it must be able to adjust its internal strategies in response to a change in the environment, to keep the system performance at a desired level. Implementing adaptive embedded systems requires specific support at different levels of the software architecture.

The most important component affecting adaptiveness is the kernel, hence specific research efforts are being devoted to flexible, as well as predictable real-time scheduling and resource management policies. However, flexibility can also be introduced above the operating system, in a software layer denoted as a middleware. To investigate such a possibility, other research groups are working on this level to introduce adaptivity and QoS management.

Some embedded systems are large and distributed among several computing nodes, hence special network methodologies are investigated to achieve adaptive behavior and predictable response. Several research efforts have also been placed in addressing wireless sensor networks (WSN), mobile ad-hoc networks MANET and other networked systems for which timeliness is still a requirement. Often such a support cannot be found in today's commercial systems.

Finally, as the complexity of real-time systems increases, high demand will be placed on the programming abstractions provided by languages. Unfortunately, current programming languages are not expressive enough to prescribe certain timing behavior and hence are not suited for realizing predictable real-time applications. As a consenquence, most of the work on programming languages for real-time applications is aimed at providing real-time functionality via language constructs rather than operating system calls.

2. State of the Integration in Europe

2.1 Brief State of the Art

The main reason for investigating adaptive real-time systems is to provide predictability and flexibility for systems and environments where requirements on resources are inherently unstable and difficult to predict in advance. Such a difficulty is due to different causes. First of all, modern computer architectures include several low-level mechanisms that are designed to enhance the average performance of applications, but unfortunately introduce high variations on tasks' execution times. In other situations, as in multimedia systems, processes can have highly variable execution times that also depend on input data [Riz06].

To prevent unpredictable performance degradations due to overloads, a real-time system must react to load variations, degrading its performance in a controlled fashion acting on system, as well as application parameters. Performing efficient QoS management requires specific support at different levels of the system architecture. Hence, new software methodologies are emerging in Embedded Systems, which strictly relate to Real-Time Operating Systems (RTOS), Middleware, and Networks.

Real-time scheduling is the kernel mechanism having the most impact on RTOS performance. Most scheduling algorithms have been developed around one of three basic schemes: table driven [Foh95], fixed priority [Aud95], or dynamic priority [Spu96]. Depending on whether scheduling decisions are resolved before or during runtime, they are classified as offline or online. Adapting to changing environmental situations may involve changes to task parameters at runtime. System wide changes, e.g., for changing operational modes in the system, have been addressed by mode change algorithms [Foh93]. Feedback scheduling changes task parameters, in particular periods [But02], to respond to online variations in the environment and current load conditions of the system. Feedback control scheduling applies control theory to estimate effects of changes and to choose parameters to provide for smooth responses and avoid instability [Cas06]. Major needs for flexible scheduling techniques are typical of industries working in consumer electronics, industrial automation, and telecommunications, as resulted from a study carried out within the ARTIST 5FP project [Bou05].

In the area of Industrial Automation, the continuous increment in processing power and memory capacity in local processors gives the opportunity to add new tasks into them, increasing system complexity in terms of supervision, diagnostics, presentation, communication, etc. Adaptive tasks scheduling that preserves the real-time constraints is a possible way to handle such situation and manage the complexity of the application.

In telecommunication companies, the main current interest seems to be in exploring the use of real-time extensions for the Linux OS. It also seems that QoS mechanisms are starting to be recognized as important for these embedded applications to increase the efficiency of subsystems and to support the possibility to serve more clients with similar levels of resources.

2.2 Main Aims for Integration and Building Excellence through Artist2

Achieving adaptivity in embedded real-time systems is a complex task that requires expertize from several disciplines, including operating systems and kernels, scheduling theory, distributed systems, network communication, control theory, quality of service management, and programming languages. Combining the results achieved in such different domains and orchestrating the various groups active in these fields is only possible by a tight interaction among the cluster participants. Hence, the aim of the integration through Artist2 is to facilitate communication among cluster members in order to:

- Improve the understanding of the key features to be added at different architecture levels (operating system, network, middleware, and language) to support adaptive real-time systems;
- Clarify the terminology to provide a common language for exchanging information between different cluster and research communities;
- Build a common operating system platform to perform experiments and develop tools that can be shared by the different research teams;
- Identify new research directions aimed at overcoming the problems encountered during the integration phase;
- Interact with industries to understand their problems and identify possible solutions;
- Form new consortia and make concrete project proposals to address specific research problems or develop critical applications of industrial interest.

2.3 Other Research Teams

The ART cluster had several interactions with the following research teams:

- University of Illinois at Urbana Champagne (reference persons: Prof. Lui Sha, Prof. Tarek Abdelzaher, and Prof. Marco Caccamo) on wireless communication protocols for real-time distributed emebedded systems.
- University of Virginia (reference persons: Prof. John Stankovic and Prof. Sang Son) on adaptive real-time systems for sensor networks.
- University of Lund (reference persons: Karl-Erik Arzen and Anton Cervin) on feedback control tecniques for adaptive real-time systems.
- University of California at Berkeley (reference person: Alberto Sangiovanni Vincentelli) on the design of component-based operating systems.
- ARTIST2 cluster on Modelling and Components, for modelling, composition, and verification of timing properties.
- Philips Research Eindhoven (reference persons: Dr. Liesbeth Steffens and Dr. Sjir van Loo) on resource management for consumer electronics.
- Ericsson Mobile Platforms (reference person: Dr. Johan Eker) on resource reservation and adaptive QoS management.
- Microchip Technology (reference person: Dr. Antonio Bersani) on real-time embedded platforms for monitoring and control.
- Carnagie-Mellon University (reference person: Prof. Raj Rajkumar) on wireless sensor networks, cooperative computing, andQoS adaptation.
- Seoul National University (reference persons: Dr. Jungkeun Park, Dr. Kanghee Kim) on distributed embedded systems and stochastic analysis of periodic task sets.
- Malardalen University, Sweden (reference person: Dr. Thomas Nolte) on integration of networked subsystems in resource constrained environments and on stochastic analysis of hybrid task sets.

2.4 Interaction of the Cluster with Other Communities

Interaction with the control community

There are at least two reasons that motivate a tight collaboration of the ART cluster with the control community. From the operating system prespective, the use of feedback control techniques allow making real-time embedded systems more reactive to environmental changes, hence system adaptivity can be improved by integrating control theory and real-time scheduling [Sta99]. From the control perspective, using flexible scheduling technologies allows making control systems more robust and predicatable: integrating feasibility analysis in the design of complex control systems allows the system designer to better analyze/control/compensate for delays and jitter caused by concurrency and intertask interference [Arz00].

Thanks to the ARTIST2 network of excellence, the ART cluster got in contact with the cluster on Control for Embedded Systems. In particular, since the first year, the two cluster leaders, Giorgio Buttazzo (ART) and Karl-Erik Arzen (Control) organized a number of meetings and workshops to exchange ideas and propose more concrete actions to make progress in this area.

A joint work involving people from Pavia, Pisa and Lund has been carried out to integrate feedback control schemes into the Shark operating system (used as a shared platform) and to investigate the effects of different scheduling policies on delays and jitter in control loops.

Another strong collaboration has been established with the hybrid systems community. As a result of this connection, Giorgio Buttazzo has been invited as a co-Program Chair to organize the International Conference on Hybrid Systems: Computation and Control (HSCC 2007).

A joint work involving people from UPC (affiliated to TUKL) and Lund has been carried out to investigate feedback scheduling techniques. A PhD student from UPC spent 5 months in Lund working on the project.

Interaction with the cluster on compilers and timing analysis

A collaboration has been started with the cluster on compilers and timing analysis to investigate the problem of enhancing the predictability of real-time systems by reducing the variability of task execution times. In fact, internal kernel mechanisms, such as scheduling, mutual exclusion, interrupt handling and communication, can heavily affect task execution behaviour and hence the timing predictability of a system. For example, preemptive scheduling reduces program locality in the cache, increasing the worst-case execution time of tasks compared with non preemptive execution.

To address these issues, a new research was initiated that looks at predictability and efficiency in a synergistic manner and that involves all levels of abstraction and implementation in embedded-system design.

Thanks to the ARTIST2 network of excellence, the ART cluster got in contact with the cluster on Compilers and Timing Analysis. The two clusters started working together to develop a new approach consisting of a combination of several methods, including (a) design-space exploration on the hardware architecture level to identify good designs offering combinations of strong performance with good predictability, (b) appropriate kernel mechanisms for task and resource management that are predictable and analyzable, and (c) a synergistic development of models, design methods and matching analysis tools that extract precise system-behaviour properties.

Interaction with the consumer electronics industry

Thanks to the International Collaboration Days organized within the ARTIST2 project, the ART cluster got in contact with two major companies, Philips and Ericsson, acting in the domain of consumer electronics. After a tight interaction with the engineers responsible for the software development process, a number of industrial needs have been identified, that would make new generation products more robust and flexible.

To cope with a constantly increasing complexity of software applications (already consisting of several million lines of code and hundreds of concurrent activities), a system supporting memory and temporal protection would allow safely mixing real-time and non real-time applications with the benefit of achieving a more scalable platform. Therefore, the work on resource reservation carried out within the ART cluster is of crucial importance to manage the increased complexity of the applications in this domain.

In addition, multimedia systems exhibit a highly dynamic behavior, since task execution times are often dependent on input data that are difficult to predict. As a consequence, these systems are prone to intermittent overload conditions that could degrade the performance in an unpredictable fashion. Again, the expertize existing in the ART cluster on overload management is of high interest for these companies, since it allows building flexible as well as predictable real-time systems that can react to load changes and perform QoS adaptation in a controlled fashion.

Interaction with the electronics industry

A new interaction of the ART cluster with Microchip Technology has been started on real-time embedded platforms for monitoring and control. In particular, the expertize existing in the ART cluster on real-time embedded control applications and real-time operating systems is extremely actractive for Microchip, who is interested in pushing the development of real-time embedded applications using 16-bit microcontrollers (as the dsPIC30 and the dsPIC33).

In this context, a big opportunity for the ART cluster is to find an agreament with Microchip to define the characteristics of a small real-time embedded platform for sensory acquisition and motor control that can be used (in conjunction with a wireless card) as a node of a mobile wirelss network. This unit would be more powerful and flexible than a mote and could be used to carry out experiments on sensor networks, embedded control, mobile robot teams and distributed control systems.

Interaction with the language community

A new activity started this year looking at real-time languages and the role they play is the development of flexible real-time systems. Considerable expertise exists within the ART cluster for this activity. In particular members of ART have participated in the development of Ada, (Ada 2005), Java (RTSJ) and POSIX (for use with C and C++). This particupation has included membership of the associted standisation bodies. The focus of the this work on languages is to link work within the cluster with international efforts across a number of languages, including but not limited to, these languages.

Participation in Standards

Some ART cluster members are actively involved in the following standardization activities:

- UML Profile QoS and Fault Tolerance
  URL: http://www.artist-embedded.org/artist/UML-Profile-QoS-and-Fault.html
  Member: Alejandro Alonso, UP Madrid.

- Ada
  URL: http://www.artist-embedded.org/artist/UML-Profile-QoS-and-Fault.html

Member: Alan Burns, Univ. of York.

- POSIX 1003
  URL: http://www.artist-embedded.org/artist/POSIX-IEEE-1003.html
  Member: Michael Gonzalez Harbour, Univ. of Catabria.

- MPEG Multimedia Middleware (M3W)
  URL: http://www.artist-embedded.org/artist/MPEG-Multimedia-Middleware-M3W.html
  Member: Alejandro Alonso, UP Madrid.

- ETHERNET powerlink
  URL: http://www.artist-embedded.org/artist/ETHERNET-Powerlink.html
  Member: Lucia Lo Bello, Univ. of Catania (affiliated to Pisa).

3. Overall Assessment and Vision for the Cluster

3.1 Assessment

During this third year of work, all the partners actively contributed to the progress of the research activities planned by the cluster. Affiliated partners gave also a substantial contribution by attending meetings, workshops, by participating in joint publications and by exchanging human resources.

The intercluster meetings and the plenary meetings organized by the project coordinator, including the review meetings, were also very fruitful for establishing new relations and opening novel interdisciplinary research directions, as the activiities with the cluster on compilers and timing analysis and with the cluster on control (as reported in Section 2.2). Indeed ARTIST2 has contributed to creating the necessary critical mass to set up the FRESCOR EU project that started in June 2006 and coordinated by University of Cantabria. Many of the ART partners involved in the activity on flexible scheduling are also partners of the project. Given such common goals, the role of the flexible scheduling activity in ARTIST2 is to:

- Bring together a wide body of expertise from the whole ARTIST2 community to come out with a broad and ambitious set of requirements for the flexible scheduling framework;
- Use that expertise to establish and later evaluate the usefulness and applicability of a contract-based specification for the framework, that allows applications to express their requirements, and the scheduler to satisfy them in the most optimal way;
- Use the ARTIST2 community as one of the ways of disseminating the results of the FRESCOR project.

With these roles in mind, this is a great situation in which the FRESCOR project can benefit from the ARTIST2 NoE expertise, and the network can benefit from being able to influence the project, and from being able to exploit its results.

Other two consortia were formed thanks to the ARTIST2 network, which made two project proposals that are still in phase of preparation, PREDATOR (coordintated by University of Saarlandes) and QUAEST (coordintated by Philips Research), both involving several members of the networks.

Another merit of the ARTIST2 network was to create a concrete opportunity for a joint research involving the ART cluster and the Control cluster. Feedback scheduling has been proven to be an efficient technique for adaptive resource management in real-time systems. It combines two disciplines: real-time systems and control systems. Although both disciplines are well stablished, a stronger interaction between them is required to fully exploit the potential benefits.

During this second year, the two clusters closely collaborated to investigate research issues that can have a significant impact in the embedded community. Moreover, the teams were also quite active in disseminating the results through workshops, scientific publications and summer schools.

A new activity on real-time languages (led by Universtity of York) was started and a series of workshops and meetings were organized. This is proving a successful way of coordinating a broad base of research on different languages taking place at a number of institutions.

The work on networks has reached several encouraging technical and scientific results during year2. The most significant results correspond to further evolutions within the FTT framework, particularly, the successful development of FTT-SE (FTT over Switched Ethernet), which has been successfully applied to dynamic QoS management with video streams and to dynamic

service composition and which seems adequate to support the contract model efficiently in distributed environments. Additionaly, a significant amount of work has been done in the design, analysis and implementation of protocols, mechanisms and paradignms for wireless sensor networks (WSN) and Mobile Ad-hoc Networks (MANETs), notably WiDOM, ART-WiSe and HYDRA.

Two problems faced during these period, which are common in research, are the difficulties in installing and understanding a complex piece of software that is an operating system and the complexity of some research jobs, which makes it difficult for a single research group to provide solutions to some industrial needs. The complementary research activities of different partners has been of primary importance for the accomplishments done during this period: the advanced resource management facilities from SHARK and MARTE could allow the development of more sophisticated QoS management algorithms.

Another problem experienced in the activity on Adaptive Resource Management for Consumer Electronics came from the fact that Philips is in the process of disentangling its semiconductor division. As a consequence, research actively involved in ARTIST are spread over both parts and it is not clear who will be where. Consequently, some of the work has been slowed down or stalled. Once the issue is settled, we expect continuation of the activities. To compensate in part, Ericson Mobile Platforms has agreed to get involved, in particular in the adaptive resource management activity. Consquently, the activity has been broadened from “consumer electronics” to “media processing”, and the number of partners involved has been reduced.

3.2 Vision and Long Term Goals

The long term goal of the ART cluster is to build the fundamental bases of a new real-time software technology that can provide a more efficient and predictable support to the development of future embedded systems, whose complexity is constantly increasing. In particular, the new software technology should

- support scalability to facilitate the porting of control applications to different platforms;
- simplify the management of resources to control the growing complexity of embedded systems;
- increase programming flexibility, for specifying functional and performance requirements that simplify test and verification;
- increase system adaptivity to react to environmental changes, still providing a sufficient level of performance;
- be robust to tolerate transient and permanent overloads conditions due to wrong design assumptions or unpredictable changes.

Using such a novel software technology would be of paramount importance for European industry, because it would allow to have a better control of complexity, so reducing the time to market. Moreover, it would improve software realiability and testabilty, so reducing the time spent in debugging.

Scientific research would also benefit from such an evolutionary change, because new tools, algorithms and kernel mechanisms will be necessary to support industry in such a transient period. In this respect, the ART cluster will play an essential role for suggesting the appropriate research directions, acting as a bridge between the academic and the industrial world.

3.3 Plans for Year 4

Concerning the JPIA activity on A Common Infrastructure for Adaptive Real-Time Systems, in the next 18 months we are planning to use Shark for understanding how to build a component-based operating system, where most of the available kernel features can be composed together to create several user-defined configurations.

In particular, a component based approach should separate mechanisms from policies in order to replace a scheduling algorithm or a resource management protocol without affecting the applications and the others components. In addition, it should allow combining different scheduling disciplines to support the development of hierarchical software architectures.

There are several benefits in adopting a component based approach at the operating system level. First of all, it would be possible to enhance the functionality of the kernel by adding new blocks, depending of the application requirements, so tailoring the kernel to the specific system to be developed. Secondly, it would facilitate and speed up the integration of novel research results, which could increase efficiency and/or predictability. Finally, it would simplify the process of porting the kernel on different platforms, so reducing the time to market and the development costs on upgrades (since only small parts should be developed).

To achieve these goals, there are several practical and theoretical problems to be solved, since most of the mechanisms implemented in a kernel (like scheduling, resource protocols, interrupt handling, aperiodic servers, synchronization and communication) heavily interact with each other and have a high degree of inter-dependencies. We plan to treat such problems by decoupling scheduling algorithms from applications, scheduling mechanisms from scheduling policies, scheduling algorithms from resource management protocols, and combining resource reservation with resource management protocols.

As for the activity on Flexible Scheduling Technologies, the first step in the work over the next period is the definition of a set of concrete requirements that provide the widest possible coverage of the needs described. Once the final set of requirements has been established, it is necessary to develop an architectural model of the framework and the applications, and describe the interfaces among them. The new framework will include all system resources in addition to the threads and networks: dynamically reconfigurable modules, multiple processors, interrupts with time protection, shared resources with time protection, memory protection, and energy/power-aware scheduling. Another goal in this period is to start the design of a quality of service manager that understands about the quality concepts of the application and translates them to the scheduling domain information that the underlying system can understand and implement, generating the contracts in an automatic or semiautomatic way.

In the next 18 months, the activity on Adaptive Resource Management for Consumer Electronics will expand the application domain to more general media processing, to provide for more industrial input, including non mass market video processing and telecommunication. It will continue to collect requirements to feed input to development of our adaptive methods, including the expanded application domain. It will expand the integration of resources to be managed jointly. With respect to scheduling and cache, it will develop algorithms to reflect on both scheduling and cache management. It will also develop algorithms for adaptation of fluctuating resources, in particular wireless bandwidth and stream transformations. Work on the use of kernels developed by partners for HOLA-QoS will continue and focus in particular on the integration of communication aspects.

As for the activity on QoS-Aware Components, the next period of time will start with the precise evaluation of the different methods achieved so far. For example, it is needed to test and measure the performance overheads caused by the new QoS management frameworks based on HOLA-QoS, MARTE and SHARK. The adaptation capabilities of HOLA-QoS will be refined in order to take advantage of the advanced resource management techniques of these kernels. The support to distribution for Java and Ada will be subject of worst-case execution analysis, in

order to have a precise knowledge of the required parameters needed to make response time analysis. It may be needed to develop specific analysis techniques for some of the potential communication protocols to be used. The results of these evaluation will guide the work of the final nine months. It is expected that some design adjustments will be done to improve the properties of these software.

For the activity on Real-Time Languages, the work on the Ada programming language will continue during the next year as patterns of use are developed, analysed and published. Work will also continue on the Real-Time Specification for Java (RTSJ) as it is also currently been updated. A number of the facilities recently incorporated in Ada 2005 are also being considered for inclusion in the RTSJ. There may also be future modifications to the provisions of POSIX that will have an influence on the use of the POSIX API in languages such as C and C++. To broaden the focus of this activity there will also be an effect during this year to produce a white paper that will summarise language development efforts over a wider constituency of languages. To this end ARTIST2 is sponsoring, and helping to organise (an ARTIST member, Burns, is co-chair) SYNCHRON'07 the International Open Workshop on Synchronous Programming: http://www.gdi.wiai.uni-bamberg.de/Synchron2007/ in Bamberg, Germany during November 2007. Work will also continue on the evaluation of Ada 2005 and the RTSJ real-time capabilities for EDF-based server scheduling (sharing and stealing servers), and the use of proof-carrying code with Ravenscar.

One of the challenges for language designers (and operating system developers) is to respond to the difficulties arising from the use of increasingly sophisticated execution platforms. These platforms have many cores and busses, networks and dynamic hardware such as FPGA. It is far from clear what the right programming abstractions are for these platforms. Even the relatively simple task of dealing with the static and dynamic placement of parallel code on SMPs is not adequately addressed in modern programming languages. The impact of platform design on language development will continue to be a focus of research that will be monitored by this activity.

The new activity on Dynamic and Pervasive Networking, will investigate distributed computing paradigms (e.g., computation of aggregate quantities, collaborative computing, reconfigurable systems) as well as dynamic QoS management, flexible scheduling and generally resource management in distributed systems, exploiting previously proposed mechanisms (e.g., MAC and routing protocols). A summer school on Real-Time Networks will be organized, involving key players from industry and academia, possibly focusing on specific topics such as WSN and MANETs. Contributions will be given to the standardization bodies (e.g., IEEE 802.15.4, IEEE 802.11.x, IEEE 802 AVBridges). Educational tools supporting teaching of industrial wired/wireless networks will be also provided. Finally, a SOTA report on WSN and MANETs will be published.

4. Cluster Participants

4.1 Core Partners

Cluster Leader **Activity Leader for "NoE Integration: Low Power"**	
	Prof. Giorgio Buttazzo Scuola Superiore Sant'Anna (SSSA), Pisa (Italy) URL: http://feanor.sssup.it/~giorgio/
Technical role(s) within Artist2	Coordinating the ART cluster and the JPIA-Platform activity entitled "A Common Infrastructure for Adaptive Real-time Systems". Providing support on real-time scheduling, operating systems, resource management, overload handling, energy aware algorithms, and quality-of-service strategies.
Research interests	Real-time operating systems, dynamic scheduling algorithms, quality of service control, multimedia systems, advanced robotics applications, and neural networks.
Role in leading conferences/journals/etc in the area	Editor-in-Chief of the Journal of Real-Time Systems (Springer). Associate Editor of the Journal of Embedded Computing (Cambridge International Science Publishing). Executive Board Member of the Euromicro Conference on Real-Time Systems. Program Chair of RTSS'01, ECRTS'03, EMSOFT'04, HSCC'07. General Chair of RTSS'02, EMSOFT'04, ECRTS'07. Reviewer for Real-Time Systems, IEEE Transactions on Computers, ACM Transactions on Embedded Computing. Program committee member of most real-time related conferences.
Notable past projects	"FIRST: Flexible Integrated Real-time Systems Technology", IST-2001-32467 (2002-2005) investigated advanced scheduling for handling applications with various real-time requirements. "OCERA: Open Components for Embedded Real-time Applications", IST-2001-35102 (2002-2005) integrated advanced real-time mechanisms in open-source kernels. "FABRIC: Federated Applications Based on Real_time Interacting Components", IST-2001-37167 (2002-2003) investigated QoS

	management methods for home networks. "ARTIST: Advanced Real-Time Systems", IST-2001-34820 (2002-2005) investigated adaptive real-time systems for QoS management. "TRACS - Flexible Real-Time Architecture for Traffic Control Systems", ESPRIT III project No. 6373 (1992-1995) investigated real-time techniques for vessel control systems.
Awards	Best paper Award at the 10th Int. Conference on Real-Time and Embedded Computing Systems and Applications (RTCSA 2004), Gothenburg, Sweden, August 2004. Paper: "The Jitter Margin and Its Application in the Design of Real-Time Control Systems". Award for the best paper and presentation at the ANIPLA Workshop on Operating Systems for Industrial Control Applications, Milan, November 18, 1999. HUSPI Award given by Honeywell for the best journal publication on robotic systems, November 1987.
Further Information	Senior Member of IEEE

Team Leader **Activity Leader for "Real-Time Languages"**	
	Professor Alan Burns University of York, UK URL: www.cs.york.ac.uk/~burns
Technical role(s) within Artist2	Undertakes research in real-time systems scheduling, particularly for flexible systems. Also concerned with the development of programming languages for this domain.
Research interests	Scheduling, languages, modelling and formal logics.
Role in leading conferences/journals/etc in the area	Previous Chair of the IEEE Technical Committee on Real-Time Systems. Edited special issue of ACM Transactions on Embedded Systems (on education).
Notable past projects	DIRC – Dependability Interdisciplinary Research Collabroations – A large, UK, 6-year, multisite project looking at dependability of computer-based systems. Burns was a PI and manged the work on temporal aspects of dependability. FIRST – EU funded project concerninf flexibile scheduling FRESCOR – EU follow on project to FIRST

Team Leader **Activity Leader for "Adaptive Resource Management for Consumer Electronics"**	
	Prof. Gerhard Fohler Technical Univeristy of Kaiserslautern (TUKL) URL: www.eit.uni-kl.de/fohler
Technical role(s) within Artist2	The role of TUKL is to investigate resource management policies for controlling the quality of service in multimedia applications. The team is leading the activity on Adaptive Resource Management for Consumer Electronics and is involved in the development and analisys of algorithms for video streaming applications. A further focus is on flexible scheduling, with the aim of integrating offline and online approaches.
Research interests	Real-time scheduling, integration of offline and online scheduling, QoS management, video streaming and media processing.
Role in leading conferences/journals/etc in the area	Chairman, technical committee on real-time systems, Euromicro Member of executive board technical committees on, IEEE real-time systems, IE embedded systems Area editor real-time, Journal of System Architecture, Elsevier Program chair, IEEE Real-Time Systems Symposium, 2006 Program chair, subtrack real-time systems, DATE 2005-2007 Program committee member of most real-time related conferences
Notable past projects	FRESCOR - Framework for Real-time Embedded Systems based on COntRacts, EU IST STREP WASP - Wirelessly Accessible Sensor Populations, EU IST IP BETSY - BEing on Time Saves energY continuous multimedia experience with low battery power, EU IST STREP FIRST - Flexible Integrated Real-Time System Technology, EU IST STREP

Team Leader **Activity Leader for "Flexible Scheduling Technologies"**	
	Prof. Michael González Harbour Universidad de Cantabria http://www.ctr.unican.es
Technical role(s) within Artist2	The role of University of Cantabria is to provide support for schedulability analysis of embedded distributed systems with real-time requirements. The Group has also developed methodologies and tools for software engineering of real-time systems in which a mixture of soft and hard deadlines can be found and as such is leading the activity on Flexible Scheduling Technologies. The group is also actively participating in the development of the Real-time POSIX operating systems standards, and is active in real-time languages, (Ada) and therefore contributing to the platform being used in the Real-Time Languages activity. One important goal of the Group has always been to test the results of basic research in practical applications. As a consequence, the Group has contacts with industrial companies in the field of industrial automation.
Research interests	Real-Time Schedulability Analysis, Real-Time Operating Systems, Real-Time Languages, Real-Time networks
Role in leading conferences/journals/etc in the area	Program chair of ECRTS 07, Program Co-Chair of the International Conference on Reliable Software Technologies 2006, Program Committee Member of RTAS, RTSS, ECRTS, and various Workshops on real-time systems.
Notable past projects	FRESCOR, Framework for Real-time Embedded Systems based on COntRacts. The FRESCOR project is aimed at developing a framework that integrates advanced flexible scheduling techniques directly into an embedded systems design methodology, covering all the levels involved in the implementation, from the OS primitives, through the middleware, up to the application level (www.frescor.org)

Team Leader	
	Prof. Luis Almeida University of Aveiro URL: http://www.ieeta.pt/lse

Technical role(s) within Artist2	Leader of the team from the University of Aveiro, participating in the ART cluster.
Research interests	Real-time communication (traffic scheduling, protocols,…) Flexible architectures for distributed embedded systems
Role in leading conferences/journals/etc in the area	Usually participates in the Organizing and /or Program Committees of conferences in the fields of Real-Time Systems (e.g., RTSS, ECRTS, RTAS) and industrial communications (e.g., WFCS, ETFA, FET). Has chaired several workshops (e.g., RTN, WTR, WiP sessions). Reviewer for several related journals (e.g., IEEE TII, TIE, TC, ACM TECS, Kluwer JRTS)
Notable past projects	ARTIST (FP5 accompaning measure). CAMBADA – Cooperative Autonomous roBots with Advanced Distributed Architecture. Specification and development of a team of cooperating autonomous robots for the Robocup Middle-Size Soccer League. Particular focus has been devoted to the architecture of each robot and their communication for information sharing. http://www.ieeta.pt/atri/cambada/ DISCO, DIStributed embeddable systems for COntrol applications. The objectives of the project were to investigate techniques and to develop solutions to improve flexibility and adaptability in distributed embedded control systems in order to reduce operation and maintenance costs while maximising the utilisation of system resources. http://www.ieeta.pt/lse/DISCO_web.pdf CIDER, Communication Infrastructure for Dependable and Evolvable Real-time systems. The project pursued two objectives: to analyse the usability of Ethernet in dependable applications (static set-up) and to devise the necessary mechanisms to allow the set-up to change dynamically (dynamic set of services and hosts) while providing the required dependability. http://www.hurray.isep.ipp.pt/activities/cider/
Awards	Best Paper Award in WFCS 2004 Best Paper Award in SICICA 2000

Team Leader	
	Professor Juan A. de la Puente Universidad Politécnica de Madrid URL: http://www.dit.upm.es/jpuente

Technical role(s) within Artist2	Team Leader of the Universidad Politécnica de Madrid, UPM leader on “Real-Time languages” and “Common infrastructure for Adaptive Real-Time Systems”
Research interests	Design of real-time systems, high-integrity systems, programming languages, scheduling, control systems and distributed systems
Role in leading conferences/journals/etc in the area	Associate editor of the Journal of Real-Time Systems. Participation in the Programme Committee of conferences such as Euromicro Real-Time Systems, International Conference on Reliable Software Technologies.
Notable past projects (optional – max 5)	ASSERT: Developmet of advance software techniques for high integrity systems for aerospace systems. TRECOM: Techniques for the development of advanced distributed real-time systems for safety and business critical systems. ORK (Open Ravenscar Real-TIme Kernel): Development of a kernel for safety-critical space systems.
Awards / Decorations	IFAC Fellow

Activity Leader for “Qos-aware components”	
	Prof. Alejandro Alonso Universidad Politécnica de Madrid. URL: http://www.dit.upm.es/aalonso
Technical role(s) within Artist2	Activity Leader for “Qos-aware components” UPM leader on Adaptive resource management for CE”
Research interests	Design of real-time systems, programming languages, scheduling, distributed systems and quality of service
Role in leading conferences/journals/etc in the area	Participation in the Programme Committee of conferences such as Euromicro Real-Time Systems, International Conference on Reliable Software Technologies.
Notable past projects	HIJA: High-Integrity Java Applications. The goal is to develop a new Java-based middleware platform fo the creation of Architecture-Neutral, high-integrity, distributed Real-Time Systems (ANRTS) ROBOCOP and Space4U. Development of component framework for embedded devices. It includes support for QoS and resource management. TRECOM: Techniques for the development of advanced distributed

	real-time systems for safety and business critical systems.

Team Leader **Activity Leader for "Dynamic and Pervasive Networking"**	
	Prof. Eduardo Tovar Polytechnic Institute of Porto (ISEP-IPP), Porto (Portugal) URL: http://www.hurray.isep.ipp.pt/asp/show_people.asp?id=1
Technical role(s) within Artist2	The role of ISEP-IPP team is to investigate distributed embedded systems, with a particular focus on communication protocols for WSN and MANETs. The team is leading the activity on Real-Time Networks and involved in flexible scheduling technologies, resource management policies and QoS-aware collaborative computing. The team has also a strong commitment in Real-Time Languages.
Research interests	Real-time systems, wireless sensor networks, multiprocessor platforms, communication networks, factory automation and system integration.
Role in leading conferences/journals/etc in the area	Executive Board Member of the Euromicro Technical Committee on Real-Time Systems. Program Chair ECRTS'05, RTN'02, WDES'06. General Chair of WFCS'00, ECRTS'03. Program committee member in several editions of ERCTS, RTSS, RTAS, RTCSA, ICDCS, SRDS, WFCS, ETFA, EMSOFT and other IEEE, ACM and Euromicro events on real-time systems, embedded systems and factory communication systems. Reviewer for Real-Time Systems, IEEE Transactions on Computers, ACM Transactions on Embedded Computing, IEEE Transactions on Industrial Informatics.
Notable past projects	"REMPLI: Real-time Energy Management via Power-lines and Internet", NNE5-2001-00825 (2003-2006) investigated advanced scheduling and protocols for power-line communication systems (PLC). "R-Fieldbus: High Performance Wireless Fieldbus in Industrial Multimedia-Related Environment", IST-1999-11316 (2001-2003), integrated advanced real-time mechanisms in hybrid wired/wireless fieldbus neworks. Mobility protocols and end-to-end deadlines.. "CABERNET: Network of Excellence in Distributed Computing Systems Architectures", IST-2000-25088 (2001-2003). "CIDER: Communication Infrastructure for Dependable Evolvable

	Real-time systems", POSI/1999/CHS/33139 (2001-2003), Portuguese Science Foundation project on real-time communication networks.
Further Information	Senior Member of IEEE

4.2 Affiliated Industrial Partners

Team Leader	
	Dr. Paolo Gai (Ph.D.) Evidence srl (Italy) URL: http://feanor.sssup.it/~pj/
Technical role(s) within Artist2	Support for the SHaRK kernel maintenance, consulting on POSIX and OSEK standards, real-time kernels, design and analysis tools.
Research interests	Real-time scheduling, operating systems, design and analysis tools.
Notable past projects	FIRST: Flexible Integrated Real-time Systems Technology, IST-2001-32467 (2002-2005) investigated advanced scheduling for handling applications with various real-time requirements. OCERA: Open Components for Embedded Real-time Applications, IST-2001-35102 (2002-2005) integrated advanced real-time mechanisms in open-source kernels. ARTIST: Advanced Real-Time Systems. (http://www.artist-embedded.org)

4.3 Affiliated Academic Partners

Team Leader	
	Prof. Lucia Lo Bello University of Catania (Italy) – Affiliated to SSSA, Pisa URL: http://www.diit.unict.it/users/llobello/
Technical role(s) within	Support for the SHaRK kernel maintenance. Implementation of

Artist2	industrial multimedia system using SHARK. Execution time measurement. Stochastic analysis of soft real-time tasks in the context of priority-driven soft real-time systems. Calculation of stochastic response time profiles of tasks that are hierarchically scheduled using server based techniques. Support for real-time communication in distributed embedded systems, with particular reference to networked embedded systems used in factory communication and in automotive environments. Real-time communication over wireless networks: modelling, timing analysis, and transmission scheduling to support soft real-time traffic over 802.11, 802.15.4 and Bluetooth networks. Design issues and protocols for wireless sensor networks and networked embedded systems.
Research interests	Real-time scheduling, overload handling, real-time communication protocols, factory communication, real-time communication over wireless networks, wireless sensor networks, automotive communications.
Role in leading conferences/journals/etc in the area	Program Chair of ETFA 05, ETFA 07. WIP Chair of ETFA 06. General Chair of ECRTS 04. PC member of many editions of ECRTS, RTSS;,RTAS,ETFA, WFCS, RTN , FET, RTNS ,WTR. Reviewer for the Real-Time Systems Journal, IEEE Transactions on Industrial Informatics, IEEE Transactions on Industrial Electronics, IEEE Transactions on Computers, Computer Standard and Interfaces, Journal of System Architectures. On the Editorial Board of the International Journal of Embedded Systems.
Notable past projects	Italian National project PRIN 04 entitled “Study and development of a realtime land control and monitoring system for fire prevention”, funded by the Italian Ministry of University and Research (http://www.prin.polito.it/) European project ESPRIT 26951 "NOAH - Network Oriented Application Harmonisation. Italian National COFIN 2001 inter-university project titled ‘’High-Performance Processing for Applications with High-Intensity Computational Requirements and Real-Time Constraints, funded by the Italian Ministry of University and Research (http://tsc.polito.it:7777/cofin2001/)
Further Information	Member of the International Electrotecnical Commission (IEC), Technical Committee SC65C, Working Group 11, Real-Time Industrial Ethernet (RTE), actively involved in standardization activities. Nominated expert member for the Italian Electrotechnical Committee (CEI-Comitato Elettrotecnico Italiano) in the Technical Committee

	SC65C “Digital Data Communications for Measurement and Control-Fieldbus for Use in Industrial Control Systems”, Maintenance Team 9, “High availability automation networks". Member of the Technical Committee on Factory Automation of the Industrial Electronics Society (IES). Co-chair of the Subcommittee 10 “Intelligent Sensors and Sensor Networks in Industrial & Factory Automation”.

Team Leader	
	Dr. Pau Martí Technical University of Catalonia, Barcelona, Spain URL: http://www.upcnet.es/~pmc16/
Technical role(s) within Artist2	Real-time systems and control systems co-design
Research interests	Real-time and control systems, overload handling, jitter analsyis and compensation, control theory.
Role in leading conferences/journals/etc in the area	Program committee member of major real-time and control conferences. Reviewer for the Real-Time Systems Journal.

Team Leader	
	Prof. Ivo De Lotto Robotic Lab, University of Pavia, Italy http://www.unipv.it/ingegneria/servizi/scheda.php?mat=000300
Technical role(s) within Artist2	Provide support for the development of real-time control applications in the domain of robotics and automation.
Research interests	Sensory systems, robotics applications, wireless communication, energy-aware computing.
Role in leading conferences/journals/etc in the area	Program committee member of major conferences on robotics. Reviewer of International journals on robotics. Member of the evaluation committee for national projects.
Awards / Decorations	Gold Medal of Italian Ministry of Education (1988)

Team Leader	
	Prof. Marisol García-Valls Universidad Carlos III de Madrid URL: http://www.it.uc3m.es/mvalls
Technical role(s) within Artist2	UC3M leader on Adaptive resource management for CE”
Research interests	Distributed embedded systems, design and modelling of real-time systems, real-time programming languages, quality of service
Role in leading conferences/journals/etc in the area	Member of the Programme Committee of conferences such as ARCS 06, EstiMedia 04-06, JTRES 03-04, EUC 05, EMSOFT 03-04 Reviewer of the Real-Time Systems Journal
Notable past projects	ARTIST: Advanced Real-Time Systems. URL: http://www.artist-embedded.org MUSE: MUlti Service Access Everywhere Everyware: Personalized services in ubiquitous environments

Team Leader	
	Prof. Julian Proenza University of the Balearic Islands URL: http://dmi.uib.es/research/SRV/jpa_ppl_en.htm
Technical role(s) within Artist2	Team leader of affiliated partner. Indirect participation in ART Cluster, with the core team University of Aveiro
Research interests	Dependable and Real-Time Systems, in particular, on fault-tolerant distributed systems, clock synchronization and field-bus networks, like CAN (Controller Area Network).
Role in leading conferences/journals/etc in the area	Chair of several workshops in his fields of interest. Participation in several Organizing and Program Committees of related events.

4.4 Affiliated International Partners

	Prof. Lui Sha University of Illinois at Urbana-Champaign URL: http://www.cs.uiuc.edu/directory/directory.php?name=sha
Technical role in Artist2	Consultant on robust real-time systems
Research interests	Distributed real-time computing systems, dynamic real-time architecture, QoS driven resource management and security and fault tolerance in networked embedded systems.
Awards / Decorations	ACM Fellow (2005) IEEE Fellow (1998) Outstanding Technical Contribution and Leadership Award, IEEE Technical Committee on Real-Time Systems (2001)

	Prof. John Stankovic University of Virginia URL: http://www.cs.virginia.edu/brochure/profs/stankovic.html
Technical role in Artist2	Consultant on sensor networks and distributed systems
Research interests	Real-time computing, embedded computing, operating systems, wireless sensor networks, and large scale distributed computing.
Awards / Decorations	BP America Professor and Chair of the Department of Computer Science in 1997. Fellow of the IEEE, a Fellow of the ACM. IEEE Award for Outstanding Technical Contributions and Leadership in Real-Time Systems, and Outstanding Scholar Award from the University of Massachusetts.

	Prof. Sanjoy Baruah University of North Carolina at Chapel Hill URL: http://www.cs.unc.edu/~baruah/
Technical role in Artist2	Consultant on multiprocessor real-time systems
Research interests	Multiprocessor Real-time Computing, Feasibility Analysis in Real-Time Systems, Overload Management in Safety-Critical Systems

5. Internal Reviewers for this Deliverable

Alessio Bechini (Univeristy of Pisa)

Tommaso Cucinotta (Scuola Superiore Sant'Anna)